558.
标题: Transmission-Line Model for Multiwall Carbon Nanotubes With Intershell Tunneling
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摘要: The electromagnetic behavior of multiwall carbon nanotubes (MWCNTs), in the frequency range where only intraband transitions are allowed, depends on the combinations of different aspects: the number of effective conducting channels of each shell, the electron tunneling between adjacent shells, and the electromagnetic interaction between shells and the environment. This paper proposes a general transmission-line (TL) model for describing the propagation of electric signals along MWCNTs at microwave through terahertz frequencies that takes into account all these aspects. The dependence of the number of conducting channels of the single shell on the shell chirality and radius is described in the framework of the quasi-classical transport theory. The description of the intershell tunneling effects on the longitudinal transport of the p-electrons is carried on the basis of the density matrix formalism and Liouville's equation. The electromagnetic coupling between the shells and ground plane is described in the frame of the classical TL theory. The intershell tunneling qualitatively changes the form of the TL equations through the tunneling inductance and capacitance operators, which have to be added, respectively, in series to the (kinetic and magnetic) inductance matrix and in parallel to the (quantum and electrical) capacitance matrix. For carbon nanotube (CNT) lengths greater than 500 nm, the norm of the tunneling inductance operator is greater than 60% of the norm of the total inductance in the frequency range from gigahertz to terahertz. The tunneling inductance is responsible for a considerable coupling between the shells and gives rise to strong spatial dispersion. The model has been used to analyze the eigen-modes of a double-wall CNT above a ground plane. The intershell tunneling gives arise to strong anomalous dispersion in antisymmetrical modes.
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